Scientizing Security

AGRICULTURAL BIOTECHNOLOGY AS CLEAN SURGICAL STRIKE

Les Levidow

Introduction

The agricultural biotechnology industry has portrayed its technical advances as essential for achieving global security. This self-portrayal can serve the public relations purposes of marginalizing political opposition and minimizing state regulation. However, the industry's language is more than merely rhetorical; it diagnoses an environmental insecurity that defines the problem for biotechnologists to solve.

When critics warn about harmful effects of agricultural biotechnology, at issue is the prevalent diagnosis for insecurity and thus the appropriate remedy. Questions include the following: Does our insecurity arise from external natural threats or from "progress" itself? Do the solutions require more genetic-level research or a different kind of knowledge? Do technical solutions discover "natural properties" or construct them?

Such issues have been theorized by the sociologist Ulrich Beck (1992), who identifies an epochal shift in the way that science treats past problems and mistakes. In primary scientization, which corresponds to early modernization, the scientific project liberates society from its preexisting dependencies upon nature. Science presupposes a clear boundary between its objects of study (the problem "out there") and itself (the solution); science objectifies errors as external problems: "Wild, uncomprehended nature and the unbroken compulsions of tradition are 'to blame' for the sicknesses, crises and catastrophes from which people suffer." Even when a scientific discipline begins to diagnose its own mistakes, it transforms them into development opportunities for further progress, while generally keeping any critical discussions away from the nonspecialized public (Beck 1992, 159–60).

Later, in secondary (or reflexive) scientization, technoscientific development is increasingly recognized as a problem for itself. As unintended consequences are anticipated by interdisciplinary approaches, different scientific disciplines confront each other publicly, thus undermining faith in progress through scientific expertise alone. Risks tend to "force new forms for the division of labour within the relationship of science, scientific practice and the public sphere" (Beck 1992, 160).

Moreover, risk debate concerns not just "secondary effects" of tech-

Social Text 44, Vol.13, No. 3, Fall/Winter 1995.

nological solutions, but also their problem-definitions. "Modernization risks are the scientized 'second morality' in which negotiations are conducted on the injuries of the industrially exhausted ex-nature in a socially 'legitimate' way, that is, with a claim to effective remedy" (Beck 1992, 81). For example, risk debate on biotechnology expresses contending ways of diagnosing the limits of chemical-intensive agriculture and thus contending remedies (Levidow 1991a).

This essay will analyze scientific and broader public debate over how biotechnology defines the security problem to be solved. In light of that debate, the conclusion will reconsider Beck's model of how technoscientific development moves from primary to secondary scientization.

Environmental Insecurities

The language of the agricultural biotechnology industry suggests that its products will be necessary to protect the common good from environmental insecurities of three kinds: demographic, commercial, and pestilential. Let us examine how these insecurities seem to require genetic remedies.

Demographic Insecurity

According to the Industrial Biotechnology Association, we must correct genetic deficiencies in order to secure and expand the food supply. That is, our society has temporarily proven Malthus wrong, because "the American farmer has adopted science and technology as rapidly as it has become available, allowing farm production to outpace population growth." Consequently, "Our existence is now dependent upon fewer than 20 species of plants; we must use all available resources to assure that [those] species are genetically fit to survive under the wide range of environmental extremes" (Calder 1991, 71). In other words, industry has promoted a genetic uniformity which makes agriculture more vulnerable to the vicissitudes of nature; this vulnerability must now be overcome by fixing the genes.

This plea extends familiar neo-Malthusian arguments that agricultural yield must keep pace with the Third World's growing population in order to avert more famines. According to Britain's single largest seeds merchant, ICI Seeds, "biotechnology will be the most reliable and environmentally acceptable way to secure the world's food supplies"; it can provide essential tools for "feeding the world" (Pike 1989; cf. GIBiP 1989; Macer and Bartle 1990). In this vein, an ad from Monsanto depicts maize growing in the desert: "Will it take a miracle to solve the world's hunger problem?"

Moreover, it is suggested that food shortages in the Third World threaten the security of the West. As one publicist argues, "We will need dramatic progress in the productivity of agriculture to limit starvation and the social chaos which overpopulation will bring. . . ." (Taverne 1990, 5). In a similar argument for biotechnological progress, a European Commission official linked agricultural and demographic threats: "Third World people do not want to emigrate, and we are not able to turn them into what we would call Europeans" (Directorate-General XII official speaking at ECAS 1992). Thus, by helping the Third World to increase agricultural yields, the West can protect itself from immigrant hordes and other environmental threats.

Commercial Insecurities

When invoking a demographic threat, industry publicists conveniently ignore the appropriation of Third World resources for producing cash-crop exports. In their account, the problem instead appears as overpopulation and inefficient agriculture. A similar diagnosis underlies structural adjustment programs (World Bank 1992), which have further dispossessed and impoverished Third World populations in the name of modernizing their countries.

The pretense of increasing food production, much less "feeding the world," is belied by the R&D priorities of the biotechnology industry. Its own house journal, *Agro-Industry Hi-Tech*, has a revealing subtitle: *International Journal for Food, Chemicals, Pharmaceuticals, Cosmetics as Linked to Agriculture through Advanced Technology*; this acknowledges the priority of making biological materials more plastic and interchangeable. The journal emphasizes the political context of reduced farm subsidies, which will make productivity less important in the future:

> Agriculture is bound to go for more [high] value-added products, better adapted to demand from downstream industry and the consumer. Hence it is going irresistibly towards a global system where contents matter more than quantities. (Anon. 1990)

For example, ICI Seeds made a strategic shift to R&D for low-volume, high value-added products in the late 1980s (Dart 1988).

In our society, what defines "value-added"? According to U.S. Tobacco's vice president, "value-added genetics determines the processability, nutrition, convenience and quality of our raw materials and food products" (Lawrence 1988, 32). Such "quality" is stamped with the commodity-form of value, as graphically illustrated in a British government publication which portrays the DNA double-helix as a money tree, sprouting £5 banknotes (DTI/LGC 1991, 26).

Concretely, some biotechnology companies are developing substitutes for crops or materials hitherto imported from Third World countries (Hobbelink 1991, 93; Walgate 1990, 57; Panos 1993, 12–14). For example, ICI Seeds (since renamed Zeneca) has increased the lauric acid content of seed, intended to substitute for tropic oils. If technically successful, these new products would undermine the livelihoods of entire Third World communities, just as European sugar beet devastated sugarcane production elsewhere.

The commercial insecurity has a domestic agenda as well as an international one. In agricultural biotechnology, transatlantic multinationals (or joint ventures) are competing against each other within Europe and the U.S., as well as competing against traditional plant breeding (Levidow 1994, 284–85). Yet their political lobbyists emphasize the imperative of strengthening European (or American) "competitiveness" against foreign rivals, supposedly so that "our society" can gain the supposed benefits; on this basis, they attack "over-regulation" as a threat to new employment. Moreover, the industry portrays its disruptive power as democratic progress:

> Let there be no illusions: as with any innovative technology, biotechnology will change economic and competitive conditions in the market. Indeed, economic renewal through innovation is the motor force of democratic societies. (SAGB 1990, 15)

These "competitive conditions" demand more flexible investment strategies in the face of an insecure commercial environment. "Value-added genetics" directs R&D towards accommodating and aggravating this commercial insecurity.

Pestilential Insecurity

Another kind of commercial insecurity faces agrochemical companies in particular. As a Du Pont official warns, "society's raised expectations of food safety and the environment have created a ground swell of public resistance to our most cost-effective pest control technology—pesticides," by which he means chemical ones (Beyer 1991, 3–4). Partly in response to this political threat, some biotechnology R&D seeks more acceptable methods of crop protection.

One line of research attempts to replace agrochemicals with new biopesticides. In particular, a gene for a toxin can be transferred from a microbe to another organism that will persist longer or target the pest more effectively. Some R&D even combines genes for different toxins in the same microbe, thus killing a broader range of insect pests (see the next section).

What problem is this solving? Traditional biopesticides have a narrow host range, which limit their commercial potential. Laments specialist Sheldon Murphy, "It is like a rifle shot rather than a shotgun shot into a pest group" (quoted in Kloppenburg 1988, 251). Microbial pesticides occupy only about 1 percent of the pesticide market, the small share due to their "lack of environmental persistence, narrow host range, limited virulence, and high production costs" (Cook and Granados 1991, 217). Likewise, the host specificity of viral pesticides also limits their market (McManus 1989, 65; Cook and Granados 1991).

The features which make biopesticides so attractive ecologically also make them unattractive economically to companies, regardless of whether the products would be attractive to farmers. The obvious solution is a genetic redesign—which can make the biopesticide less specific, more persistent, and/or more deadly. In such ways, biotechnology may overcome the economic limitations of traditional biopesticides. Thus "value-added genetics" defines the pestilential insecurity to be overcome.

The true believers of chemical omnipotence have not readily accepted the systemic limits of deadly cleanliness.

Cleaner Defense?

In strengthening genetic defenses, biotechnologists reconceptualize the type of "clean" nature which will make agriculture safe from pests. Let us examine the historical shift in defining a "cleaner defense."

Deadly Cleanliness

In the industrialized agriculture that prevailed after World War II, plant breeders could select crop strains mainly for high yield; the "pesticide umbrella" protected crops from insects, weeds, and disease. Farmland was kept "clean" of intruders—indeed, of all other life. The soil became less able to regenerate itself; its fertility came to depend upon applying chemical fertilizer rather than recyling vegetation or manure. As a cultural critic has observed, "That ultimate simulacrum of our times—artificial shit—is surely the sign of a culture obsessed with what Baudrillard calls 'deadly cleanliness'" (Nelson 1990).

Since the 1960s, the chemicals have been losing both their clean image and agronomic effectiveness. Genetic uniformity has left crops more vulnerable to pests and disease. Pesticides have eliminated the natural predators of pests, and prolonged use has generated selection pressure for insect pests resistant to the chemicals. Agriculture has faced a "chemical treadmill," needing new pesticides to keep up with new pest resistance.

Despite applying more and newer pesticides, agriculture has suffered even greater crop losses—widely attributed to intensive monoculture methods, which abandoned such traditional practices as crop rotation (Pimentel 1989, 70). Meanwhile, extremely little of the pesticide has actually reached target insects (Pimentel and Levitan 1986). More and more fertilizer has been needed to sustain crop yields, yet fertilizers assist weeds. Environmental protest has cited threats to human and environmental safety from chemical residues or runoff, in turn leading government to restrict pesticide use, especially of older chemicals.

The true believers of chemical omnipotence have not readily accepted the systemic limits of deadly cleanliness. For example, when the U.S. Department of Agriculture abandoned the goal of eradicating the fire ant in 1975, it blamed EPA restrictions for turning USDA efforts "into a control program of living with the ants rather than working towards an eradication program to wipe them out." Yet no widespread insect pest has been entirely eradicated. Meanwhile, ecologists have challenged the illusion of permanent success; they have urged farmers to develop integrated biological-chemical methods (Erlich et al. 1977, 646–49). Advisors have warned against assuming that "there exists a scientific-technological fix for any agricultural problem" (Schoorl and Holt 1990, 164).

Nevertheless, the search continues for such a fix. For some designers of "clean technology," farming is an engineering process, to be more precisely controlled with the help of information technology. This way, farmers can avoid reducing chemical use to the point of losing control:

> Continuing downward revision of levels would make today's environmental solution into tomorrow's problem. A potential problem with the use of low-dose treatments is the development of pesticide resistance where members of the population least influenced by the low-dose treatment survive and multiply. (SERC 1992, 8–9)

In effect, they warn that the chemical defense may be inadequately precise and powerful to counter the external natural threat. In proposing its cleaner method of defense, the technological solution predefines the problem to be solved.

Recently agronomists have been acknowledging the limits of overcoming pest problems through better chemicals alone. However, industry now tends to locate the problem within genetic deficiencies, which can be corrected by inserting extra genetic defenses into crops or biopesticides (as discussed earlier). Emphasizing their own selective precision, one biotechnologist notes that genetic modification provides the plant breeder with "more ammunition to help him hit his target" (Lindsey 1991, 9).

In this way, biotechnological methods are accorded a natural legitimacy. According to the president of Mycogen Corporation, "What is new is our growing ability to simulate nature in ways that can offer enormous benefits" (Calder 1991, 75; see also Goodman 1989, 49). Biotechnology promises us a safer, cleaner version of nature: through precision engineering, it replaces chemical with genetic control, while redefining biology in chemical terms.

For example, in going beyond chemical fertilizers, biotechnologists are attempting to modify nitrogen-fixing bacteria for greater effectiveness, though with little success so far. In retrospect, artificial shit was only the penultimate simulacrum of nature. Now genetic reprogramming offers an even better, more "natural" version.

Within agricultural biotechnology, the greatest R&D efforts are directed at developing herbicide-resistant crops. Their inserted gene protects the crop from broad-spectrum herbicides, which in turn kill all other vegetation. Previously agronomists had to find herbicides which would selectively spare the crop from damage; now the inserted gene provides the selective protection. As ICI Seeds describes this strategy, "A set of single-gene resistances to broad-spectrum herbicides will enable the farmer to benefit from crop-weed selectivity through genetics rather than chemistry" (Dart 1988, 9).

By inserting a gene which offers resistance to a less persistent herbicide, industry can describe the product as cleaner, in the dual sense of combining a precise defense with a less-polluting chemical. According to ICI Seeds, herbicide-resistant crops will reduce dependence upon chemical inputs by reducing quantities of their use; such crops will offer greater choice to farmers, who can thereby defer herbicide applications until the post-emergence phase (Bartle 1991). Such products have been celebrated as the ultimate solution to the problem of weeds resistant to herbicides—even as a "moral imperative" for feeding the Third World (Gressel 1993).

Meanwhile this R&D agenda has been denounced for perpetuating dependence upon chemical herbicides, regardless of whether quantities are reduced (BWG 1990). Ecologists remind us that some herbicides have already weakened the crop's natural defenses and so necessitated additional chemical treatments (Pimentel 1987). In various ways, herbicide-resistant crops could mean extending the use of agrochemicals, in time or space.

Herbicide-resistance R&D has an analogy in insect control. Agronomists have already used traditional breeding methods to select for beneficial insects resistant to insecticides—in particular, for predatory mites which control fruit pests (Hoy 1987; Cook and Granados 1991, 215). Now biotechnologists are searching for the genes which protect the insects (Ffrench-Constant et al. 1991). By engineering these genes into some insects, biotechnology can help justify the agricultural practice of applying broad-spectrum insecticides, which kill all other insects. This strategy presumes that biological research can identify, genetically modify, and thus protect all beneficial insects—notwithstanding great disagreements about how to do so.

Biotechnological Omnipotence

Underlying such R&D priorities is a fantasy of biotechnological omnipotence: genetic defenses somehow overcome the limits of intensive monoculture, by treating this monoculture's problems as external ones. In this vein, imagine a "supercrop" which has been genetically modified for resistance to both insect attack and high doses of herbicide. Such an imaginary crop is depicted in a textbook for schoolchildren, sponsored by Britain's Department of Trade and Industry (Satelle 1988, 31). This supercrop exemplifies the declaration by an industry publicist: "If we have the imagination and resources, there is almost no biological problem we cannot solve" (Taverne 1990, 4).

Not merely rhetorical, such fantasy has roots in the conceptual framework of biotechnology: reprogramming nature for total environmental control. In the 1930s, the new science of molecular biology treated genetic material as interchangeable, universally coded "information," which would permit the ultimate human control over the "essence of life" (Yoxen 1983). With the cell conceptualized as a natural factory, the "factory farm" also becomes more than a metaphor (Krimsky 1991, 10).

Indeed, genetic engineering invests nature with computer and industrial metaphors, which in turn lend a natural status to its products. Emphasizing the universal code in nature, Monsanto (1984) presented genetic engineering as a "natural science." Paradoxically, biotechnology does what nature does—but does so more safely and efficiently (Kleinman and Kloppenburg 1991).

By the late 1980s, the language shifted to genetically engineered to genetically *modified* organisms (GMOs), the new term denoting a modest improvement upon nature. Genetic modification precisely enhances natural characteristics—for example, by "giving nature a little nudge towards greater efficiency," according to ICI (1989). Akin to nature, and protective of nature, GMOs can appear to provide an enhanced natural efficiency through "environment-friendly products" (Levidow and Tait 1991). Through this rhetorical greening, biotechnology can be promoted as "clean technology."

According to one definition, clean products and processes are "as subtle and precise as natural processes . . . [and] as sustainable as nature is without human interference" (SERC 1990). This account begs the question of what values are to be sustained in the attempt at simulating a natural precision—as if the "human interference" could be minimized or neutral. In the case of biotechnology, humans reconstruct nature to embody industrial efficiency, taking its problem-definitions from within intensive monoculture. It is an attempt at total biosystems control by manipulating a few genetic and/or chemical parameters (Kloppenburg 1991).

Like the strategy of purely chemical control, this genetic-level control treats the systemic instabilities of intensive monoculture as external natural threats. Deploying a precise genetic defense, possibly combined with a broad-spectrum chemical offense, biotechnology offers a clean surgical strike against unruly nature.

Genetic Treadmill

Can biotechnology achieve total control over pests? If not, then what counts as success? Let us examine expert disagreements over R&D strategy for new biopesticides.

A traditional biopesticide, Bacillus thuringiensis (Bt), has been widely used in agriculture. Commercialization expanded in the late 1960s, after isolating a Bt strain which was particularly effective against Lepidopteran pests (McManus 1989, 62–63). Bt is also the potential basis for new biopesticides, as it has numerous varieties, each of which produces a toxin specific to certain insects. The corresponding genes are being identified and transferred into more persistent organisms, be they other microorganisms or even plants.

According to Calgene's vice president, such research attempts "to do better than mother nature in designing improved, more efficacious toxins" (Goodman 1989, 52)—or rather, in using old toxins more effectively. Another leading company in biopesticides, Novo Nordisk, portrays their benign surgical precision with the visual metaphor of a green bow-and-arrow: "Fighting for a better world, naturally."

Regardless of their precision and biological origin, the new biopesticides pose a familiar hazard: generating selection pressure for resistant pests. If such resistance undermines the effectiveness of traditional biopesticides as well as the new ones, then it will eliminate a relatively safe alternative to chemicals (as some environmentalists have warned, for example, NWF 1992). Such warnings have been strengthened by scientific reports that pests are developing resistance to Bt in stored grain, and even to Bt in the field (McGaughey 1985; Tabashnik et al. 1991). As a journalist noted, "Mother Nature has startled the genetic scientists" (Connor 1991), though they were startled only because they had tunnel vision.

DNA as Chemical Bullets

To avoid the scenario of pest resistance, scientists have been discussing strategies such as integrated pest management (IPM). In the case of chemical pesticides, even a leading advocate of IPM has suggested that it "will only slow the pesticide treadmill, thereby extending the usefulness of available chemicals" (Hammock and Soderlund 1986, 113). By analogy, can genetically modified biopesticides be designed to avoid a "genetic treadmill," or just to slow it down?

Some scientists warn that a genetic treadmill will result from any attempt at totally exterminating a pest. They seek alternative strategies which can "outwit evolution" by minimizing selection pressure for resistant pests. Early in the Bt debate, a Calgene official suggested using genetically modified Bt "to control [insect] populations rather than kill insects outright" (Goodman 1989, 52).

Some strategies, amenable to integrated pest management, have been proposed by entomologists and endorsed by some industrialists (for example, Gould 1988; Tabashnik et al. 1991; Goodman 1989; Cutler 1991). On the military analogy of a "safe haven" (Coombs 1993), farmers could provide refugia, that is, patches of toxin-free plants, so that the less resistant insects can survive and pass on their genes to progeny; and/or farmers could vary the choice of toxin over space and time. However, even proponents of the refugia strategy acknowledge great difficulties in designing and implementing it, partly because the necessary measures would impose commercial disadvantages upon farmers and/or seed vendors (Holmes 1993). The strategy assumes a willingness to sacrifice economic benefits, in favor of the common good.

Such attempts at integrated pest management may benefit from new genetic knowledge. At Plant Genetic Systems in Belgium, laboratory research has clarified that pest resistance to the different Bt toxins is controlled independently, by different genes (Peferoen 1991; van Rie 1991). Such knowledge implies that varying the toxin over time could help prevent pest resistance. However, one PGS researcher downplays IPM strategies, instead arguing that a strategy of "insecticide mixtures would be more effective": this would kill all the insects because few or none would be resistant to more than one toxin. He concludes that "the optimal strategy for pest management will depend upon the genetic basis for resistance" (van Rie 1991, 179).

His more cautious colleagues at PGS foresee new biopesticides bringing a massive introduction of Bt in soils; they warn that "we know almost nothing about its ecology" (Lambert and Peferoen 1992, 120–21). Moreover, the strategy of mixing toxins would have to be executed perfectly in order to succeed; otherwise it would generate multiply resistant pests—a "superpest" (as a Du Pont scientist warns, quoted in Holmes 1993, 36). Additional field testing has shown that moderately resistant insects can evolve resistance to Bt mixtures (Tabashnik et al. 1991); such commercial products seem likely to generate a genetic treadmill.

Nevertheless, the prevalent R&D treats genes as chemical bullets for a total extermination strategy. For example, biotechnologists develop "cassettes" for inserting several defense genes at once into a plant or microorganism (Day 1993, 39). Why? This strategy happens to coincide with commercial pressures for combining different genetic defenses within the same "product"—in effect, treating crop vulnerability as an external problem of pest genetics. A refugia strategy is probably more effective for avoiding pest resistance, but simpler strategies—such as toxin mixtures—would be more profitable for industry (according to USDA scientists, McGaughey and Whalon 1992, 1455).

And what if a "genetic treadmill" ensues? According to Jerry Caulder, president of Mycogen Corporation, insects have understandably acquired resistance to the one strain of Bt which has been used for thirty years, but "[w]e have other bullets in the gun we call Bt" (Cutler 1991, 7). From this cornucopian perspective, any one toxin is dispensable, because scientists will always find another one to kill the same pest. Indeed, some researchers are already devising plans to add new toxins faster than the insect pests can develop resistance to the old ones (Wilson et al. 1992). Thus a prospective "genetic treadmill" is treated as a further opportunity for technical advance and commercial advantage, rather than as a serious hazard; it is cast as a matter for specialist problemsolving, rather than for an interdisciplinary problem-*redefinition*.

Following a long history of technological models for socioenvironmental control (Kwa 1994), biotechnology extends these models to the molecular level, while redefining the environment and life itself. Biotechnology promises a naturally based alternative to agrochemicals, yet its dominant paradigm conceptualizes DNA as the ultimate chemical weapon. As an historical precedent, medicine has appropriated military metaphors in developing new weapons which can seek and destroy invading pathogens (Montgomery 1991). Both the medical and military metaphors converge in biotechnology: here DNA becomes a magic bullet for "cleaning up on the farm," in both senses of that verb (Levidow 1991a).

Although the new biopesticides become more like chemical pesticides, they still remain "clean" of toxic residues and precisely targeted on insect pests—at least in theory. With their single-gene defense or multigene offense, they aim for a clean surgical strike. Although one entomologist, Fred Gould, remains skeptical of these solutions, he too speaks in military metaphor: he celebrates the selectivity of Bt toxins, each of which is "like a surgical tool for taking out the pest" (quoted in Holmes 1993, 34).

What about collateral damage from biotechnology? For example, even some traditional biopesticides can harm nontarget organisms (Pimentel 1989, 62). Safety regulation attempts to anticipate any direct harm from new biopesticides, especially those with Bt toxins (for example, Cavalieri 1991). However, the hazard of a "genetic treadmill" lies outside the authority of environmental safety regulation (Fox 1991).

Stereotypically, risk-management measures have been characterized as keeping biotechnology safe for the environment. By contrast, a heretical philosopher has characterized both the technology and its regulation as a new environmental engineering, "making nature safe for biotechnology"—for instance, by redesigning rural environments on economic criteria (Sagoff 1991). Similarly, such criteria guide crop-protection R&D in transforming biopesticides and agricultural systems (as in the Bt example above); in so reconstructing nature, biotechnology may intensify systemic hazards which lie beyond any formal regulation.

In particular, the term *biodiversity* comes to mean new combinations of special protective genes in crop strains. Traditionally, diverse cultivars (and biopesticides) provided a systemic defense against unanticipated pests or disease. Their diversity now becomes a resource for genetic prospecting, for extracting a few magic bullets which can provide high value-added commodities. In this vein, an organic farmers' organization has warned that "supercrops" may encourage farmers to buy seed anew each season rather than sow seed harvested from the previous year's crop;

the resulting "global monoculture" will become all the more vulnerable to pests and disease (quoted in Day 1993).

Some critics have attributed these agricultural problems to our intensive monocultural system, driven by the imperatives of profitability and perpetuated by the genetic solutions of biotechnology (for example, Doyle 1985; Hobbelink 1991). Toward a sustainable agriculture, critics propose "holistic" methods of crop protection, such as those which have traditionally helped to avoid weeds, pests, and disease: "It is widely agreed that systems approaches—for example, crop rotation and other methods—could avoid the need for the majority of pesticides, both chemical and biological, now and into the future" (Mellon 1991, 67).

A prospective "genetic treadmill" is treated as a further opportunity for technical advance and commercial advantage, rather than as a serious hazard.

For some alternatives, proponents idealize traditional methods as proximate to nature: "The closer a farming system comes to a natural ecosystem, the most likely it is to be sustainable" (Hobbelink 1991, 140). On this model, society can appropriate benign ecological processes for an agricultural system; such an approach would keep the system clean of high-tech inputs, seen as artificial contaminants.

In these antagonistic accounts of "clean" agriculture, we can analyze a conflict between models that either idealize or demonize some external nature. At the same time, such concepts mediate a struggle over farmers' social power. Biotechnologists emphasize that modern pest-control methods can reduce farm management time (for example, Goodman 1989, 84–86); this model presupposes and reinforces class divisions within agriculture. Critics foresee biotechnological methods dispossessing farmers of their knowledge and skills, which alternative methods could strengthen (Hassebrook 1989). For example, IPM requires skillfully monitoring insect pests, yet a total extermination strategy would initially spare too few insects to warrant monitoring the fields.

Also at issue is the meaning of "sustainable agriculture"—more than about sustaining quantitative yields. For example, a conference workshop queried whether "sustainable agriculture" signifies only an environmental equilibrium or also a way of life (MacDonald 1989, 20). The question could be extended by asking how any model of agricultural stability tends to favor one way of life rather than another (Hamlin 1991).

At stake here is not simply collateral damage or "secondary consequences," but the primary forces which shape agronomic knowledge and control. Alternative methods, and their ecological basis, have obtained little research funding. U.S. government funds have been shifting towards "biotechnological product development, rather than biological process understanding" (Doyle 1990, 191). As a leading biotechnologist proclaimed, "This is the era of biology, and *we* are the biologists"—meaning not ecologists or even agronomists (cited in Levidow 1991b).

Such conflicts are marginalized by advocates of more biotechnological science. For example, the editor emeritus of *Farm Journal* welcomes biotechnology products for correcting past mistakes:

> it is not science that errs; it is our use of science or, more likely, our failure to use science, that leads us into errors. Science is a carefully constructed method or procedure by which we can discover our errors and move toward truth (cited in Goodman 1989, 56).

In this stereotypical account, undesirable consequences arise from failing to follow the scientific method—for example, from misperceiving the truth.

On the contrary, biotechnology R&D restricts the range of possible "truths" to those that can help correct genetic deficiencies, and so help strengthen a good Mother Nature against the external threat of a bad, unruly nature. R&D makes unacknowledged value-choices by investing nature with military and medical metaphors, with computer codes, and with value-added genetics. Indeed, biotechnology extends the earlier metaphors of "machine and market" which originally redefined agricultural land as capital in the eighteenth century (Williams 1980, 73, 79). By updating these capitalist metaphors, biotechnology naturalizes its project of reconstructing the environment for a molecular-level control.

Conclusion: Scientizing Security

Agricultural biotechnology faces a scientific and wider public controversy over how to define the "insecurity" that needs to be overcome. Interdisciplinary disagreements present greater opportunities for critics to challenge the dominant problem-definition. Even some innovators and advisers acknowledge the disruptive potential of prospective biotechnological products. Yet the R&D priorities remain entrapped within a self-perpetuating logic, preparing yet more technofixes for the problems created by the present ones.

Industry claims that biotechnology will help to "feed the world" and thus to avert a global demographic insecurity, while critics warn that some products may undermine Third World livelihoods or make farmers more dependent upon purchased inputs. Guided by "value-added genetics," biotechnology seeks genetic characteristics that will enhance the market value of new products. These may flexibly accommodate or even intensify commercial insecurities in the name of protecting society from external competitive threats.

Biotechnological research also seeks to overcome a pestilential insecurity, yet it assumes that genetic deficiencies make crops vulnerable to pests, or render biopesticides unviable economically. In developing more powerful biopesticides, researchers acknowledge a prospective "genetic treadmill" yet treat this problem as a technical challenge and commercial opportunity. Metaphorically, the prevalent R&D treats genetic diversity as a gene bank for extracting a few magic bullets which can control pests and avoid pest resistance.

Such approaches treat the systemic instability of intensive monoculture as if it were mainly an external threat posed by unruly nature. Thus a clean surgical strike can provide a more precise and lethal defense. By analogy to the New World Order, a global control system manages and intensifies its own endemic instabilities, while attributing these to an external enemy (Levidow 1995).[1]

Questioning those models, some entomologists and agronomists locate an endemic pestilential insecurity in the capacity of pests to overcome any attempt at eliminating them. Cautious voices recommend agronomic strategies that minimize selection pressure for resistant pests rather than maximize their extermination; otherwise, genetically modified biopesticides may undermine the effectiveness of both traditional and new biopesticides. Some critics go further by attributing environmental insecurity to genetic uniformity—that is, to the intensive monocultural system which has resulted from industrializing agriculture.

Partly at issue here is how to diagnose the problems of chemical-intensive agriculture, whose past damage well exemplifies "the industrially exhausted ex-nature" (Beck 1992, 81). "Mistakes," both past and present, offer a development opportunity for new biotechnology products. R&D strategies rest upon a fantasy of biotechnological omnipotence; for example, one biopesticidal strategy must presume that pest-management measures could work perfectly. "Even trying to establish something like a perfect system would mean to establish perfect control, some kind of dictatorship in everyday life," argues Ulrich Beck (1992, 30).

Different concepts of nature, implying different kinds of expertise, are proposed for scientizing environmental security. Biotechnology imagines and designs a precision-control nature which tames or utilizes an unruly nature. When its critics counterpose an idealized version of ecological "nature," they engage in a cultural conflict over how to reconstruct nature and the scientific division of labor.

It is a conflict not simply over how to apply new scientific knowledge, but also over how to generate that knowledge across disciplines. It entails a cognitive struggle over whether (or how) to acknowledge the fundamental source of agronomic problems in scientization itself. In reifying environmental insecurity as a genetic deficiency, biotechnology provokes political challenges to its legitimacy.

Biotechnology imagines and designs a precision-control nature which tames or utilizes an unruly nature. When its critics counterpose an idealized version of ecological "nature," they engage in a cultural conflict over how to reconstruct nature and the scientific division of labor.

In these ways, agricultural biotechnology manifests features of "reflexive scientization," though somewhat differently than suggested by Beck's model. Beck theorizes a transition between historical stages, yet biotechnology R&D manifests tensions between primary and secondary (reflexive) scientization—that is, between denying versus acknowledging the internal systemic sources of environmental insecurity. Beck emphasizes disputes over unintended "secondary consequences," yet also at issue are the primary causes[2]—that is, the genetic reductionism and commodity form which guide the restructuring of agriculture, along with its sociotechnical division of labor.

In scientizing security, agricultural biotechnology directs its genetic-level remedies at unruly nature and at its own disruptive effects. So far, it has marginalized any liberatory potential of the reflexive scientization that Beck theorizes.

Notes

This essay arises from two studies: "Regulating the Risks of Biotechnology" (project number R000 23 1611), and "From Precautionary to Risk-Based Regulation" (project number L211 25 2032), both funded by Britain's Economic and Social Research Council. I would like to thank David Pimentel, Frederick Buttel, and Roger Wrubel for helpful editorial comments on an earlier version. I would also like to thank the anonymous referees of the journal *Politics and the Life Sciences*, whose editor rejected this essay as "not ready for publication"; I wonder who was not ready.

1. The title of my essay intends more than a rhetorical analogy to the Gulf War. In that episode, the Western powers claimed to execute clean surgical strikes, whose supposed precision lent moral authority to the attack on an irrational, evil enemy (Aksoy and Robins 1991). Yet this supposed enemy was both a material and ideological projection of their own regional "security" system. Moreover, Saddam Hussein's regime emerged stronger from the episode, perhaps not accidentally. In various ways, the West aggravated and portrayed a systemic instability as if it were an alien, external threat (Midnight Notes 1992; Levidow 1995).

2. In emphasizing primary causes, I intend an analogy to Aristotle's concept of "final cause". This was a teleological explanation which Francis Bacon banished from modern Western science—in favor of the "efficient cause," the moving force which creates or transforms a substance (Proctor 1991:41–42). By emphasizing only the latter concept of cause, scientific disciplines tend to deny or ignore the human purposes which predefine the problem to be solved; thus science can regard its own control strategies as merely reflecting or discovering natural forces.

References

Agro-Industry Hi-Tech. 1990. Editorial. 1, no. 1: 3–4.

Aksoy, Asu, and Kevin Robins. 1991. Exterminating angels: Morality, technology and violence in the Gulf War." *Science as Culture* 2, no. 3: 222–36.

Bartle, Ian. 1991. *Herbicide-tolerant plants: Weed control with the environment in mind*. Haslemere, Surrey: ICI Seeds [now Zeneca].

Beck, Ulrich. 1992. *Risk society: Towards a new modernity*. London: Sage.

Beyer, Elmo. 1991. Crop protection: Meeting the challenge. *Agro-Industry Hi-Tech* 2, no. 6: 3–4.

Biotechnology Working Group (BWG). 1990. *Biotechnology's bitter harvest: Herbicide tolerant crops and the threat to sustainable agriculture*. New York: Biotechnology Working Group (c/o Environmental Defense Fund, N.Y.).

Calder, Jerry. 1991. Biotechnology at the forefront of agriculture. In *Agricultural biotechnology at the crossroads: Biological, social and institutional concerns*, edited by June F. MacDonald. Ithaca, N.Y.: National Agricultural Biotechnology Council.

Cavalieri, Liebe. 1991. Scaling-up field testing of modified microorganisms. *BioScience* 41, no. 8: 568–74.

Connor, Steve. 1991. Mother Nature thwarts hopes of supercrops. *Independent*, 17 November.

Cook, R. James, and Robert R. Granados. 1991. Biological control: Making it work. In *Agricultural biotechnology at the crossroads: Biological, social and institutional concerns*, edited by June F. MacDonald. Ithaca, N.Y.: National Agricultural Biotechnology Council.

Coombs, Roger. 1993. Bt: The success story continues. *Agro-Industry Hi-Tech* 4, no. 6: 7–9.

Cutler, Karol. 1991. Bt resistance: A cause for concern? Industry says: No need for panic. *Ag Biotech News* 8 (January/February): 7.

Dart, Ed. 1988. *Development of biotechnology in a large company*. London: ICI External Relations Department.

Day, Stephen. 1993. A shot in the arm for plants. *New Scientist*. 9 January, 36–40.

DTI/LGC. 1991. *Biotechnology: A plain man's guide to the support and regulations in the UK*. Hobsons/Laboratory of the Government Chemist, Department of Trade and Industry.

Doyle, Jack. 1985. *Altered harvest: Agriculture, genetics and the fate of the world's food supply*. New York: Viking.

———. 1990. Who will gain from biotechnology? In *Agricultural bioethics: Implications of agricultural biotechnology*, edited by S. Gendel et al. Ames: Iowa State University Press.

ECAS. 1992. Report on "European citizens audit on biotechnology." *Le citoyen européen*, no. 17. Brussels: Euro-Citizen Action Service [but does not include quotation cited in my article].

Erlich, Paul, Ann Erlich, and John Holdren. 1977. *Ecoscience: Population, resources, environment*. San Francisco, Calif.: W. H. Freeman.

Fischhoff, David. 1992. Management of lepidopteran pests with insect resistant cotton: Recommended approaches. *Beltwide Cotton Conference Proceedings*. 16 (August).

Fox, Jeffrey. 1991. Bt resistance prompts early planning. *Bio/Technology* 9: 1319.

Ffrench-Constant, R., D. P. Mortlock, and C. D. Shaffer. 1991. Molecular cloning and transformation of cyclodiene resitance in Drosophilia: An invertebrate gamma-aminobutyric acid subtype A receptor locus. *Proceedings of the National Academy of Sciences* 88, no. 16: 7209–13.

GIBiP. 1989. *Towards a sustainable future*. The Hague: Green Industry Biotechnology Platform/Switzerland: International Association of Plant Breeders.

Goodman, Robert M. 1989. Biotechnology and sustainable agriculture: Policy alternatives. In *Biotechnology and sustainable agriculture: Policy alternatives*, edited by June F. MacDonald. Ithaca, N.Y.: National Agricultural Biotechnology Council.

Gressel, Jonathan. 1992. Genetically-engineered herbicide-resistant crops: A moral imperative for world food production. *Agro-Industry Hi-Tech* 3, no. 6: 3–7.

———. 1993. Herbicide resistance threatens wheat supply. *Agro-Industry Hi-Tech* 4, no. 2: 36.

Gould, Fred. 1988. Genetic engineering, integrated pest management and the evolution of pests. In *Planned release of genetically engineered organisms*, edited by J. Hodgson and A. M. Sugden. Cambridge: Elsevier, S15–18.

Hamlin, Christopher. 1991. Green meanings: What is sustained by sustainable agriculture? *Science as Culture* 2, no. 4: 507–37.

Hassebrook, Charles. 1989. Biotechnology, sustainable agriculture and the family farm. In *Biotechnology and sustainable agriculture: Policy alternatives*, edited by June F. MacDonald. Ithaca, N.Y.: National Agricultural Biotechnology Council.

Hammock, Bruce, and David Soderlund. 1986. Chemical strategies for resistance management. In *Pesticide resistance: Strategies and tactics for management*, prepared by National Research Council. Washington, D.C.: National Academy.

Hobbelink, Henk. 1991. *Biotechnology and the future of world agriculture*. London: Zed.

Holmes, Bob. 1993. The perils of planting pesticides. *New Scientist*, 28 August, 34–37.

Hoy, Margaret. 1987. Developing insecticide resistance in insect and mite predators and opportunities for gene transfer. In *Biotechnology in agricultural chemistry*, edited by H. M. LeBaron. Washington, D.C.: American Chemical Society.

ICI. 1989. *Annual Report 1988*. London: Imperial Chemical Industries.

Kleinman, Daniel L., and Jack Kloppenburg. 1991. Aiming for the discursive high ground: Monsanto and the biotechnology controversy. *Sociological Forum* 6, no. 3: 427–48.

Kloppenburg, Jack. 1988. *First the seed: The political economy of plant biotechnology, 1492–2000*. Cambridge: Cambridge University Press.

———. 1991. Alternative agriculture and the new biotechnologies. *Science as Culture* 2, no. 4: 482–506.

Krimsky, Sheldon. 1991. *Biotechnics and society: The rise of industrial genetics*. London: Praeger.

Kwa, Chunglin. 1994. Modelling technologies of control. *Science as Culture* 4, no. 3: 363–92.

Lambert, Bart, and Marnix Peferoen. 1992. Insecticidal promise of Bacillus thuringiensis. *BioScience* 42, no. 2: 113–21.

Lawrence, Robert H. 1988. New applications of biotechnology in the food industry. In *Biotechnology and the food supply*. Washington, D.C.: National Academy.

Levidow, Les. 1991a. Cleaning up on the farm. *Science as Culture* 2, no. 4: 538–68.

———. 1991b. Biotechnology at the amber crossing. *Project Appraisal* 6, no. 4: 234–38.

———. 1994. Biotechnology regulation as symbolic normalization. *Technology Analysis and Strategic Management* 6, no. 3: 273–88.

———. 1995. The paranoid rationality of the Gulf War. *Psychoculture* 1, no. 1: 9–16; a shorter version appears as The gulf massacre as paranoid rationality. In *Culture on the brink: Ideologies of technology*, edited by G. Bender and T. Druckrey. Seattle, Wash.: Bay (1994).

Levidow, Les, and Joyce Tait. 1991. The greening of biotechnology: GMOs as environment-friendly products. *Science and Public Policy* 18, no. 5: 271–80.

Lindsey, K. 1991. Crop improvement through biotechnology. *Agro-Industry Hi-Tech* 2, no. 4: 9–16.

McGaughey, William. 1985. Insect resistance in the biological insecticide Bt. *Science* 229: 193–95.

McGaughey, William, and Mark Whalon. 1992. Managing insect resistance to Bacillus thuringiensis toxins. *Science* 258: 1451–55.

MacDonald, June F., ed. 1989. *Biotechnology and sustainable agriculture: Policy alternatives*. Ithaca, N.Y.: National Agricultural Biotechnology Council.

———., ed. 1991. *Agricultural biotechnology at the crossroads: Biological, social and institutional concerns*. Ithaca, N.Y.: National Agricultural Biotechnology Council.

McManus, Michael. 1991. Biopesticides: An overview. In *Biotechnology and sustainable agriculture: Policy alternatives*, edited by June F. MacDonald. Ithaca, N.Y.: National Agricultural Biotechnology Council.

Macer, Richard, and Ian Bartle. 1990. *Crop biotechnology in the developing world*. Fernhurst, Surrey: ICI Seeds [now Zeneca].

Mellon, Margaret. 1991. Biotechnology and the environmental vision. In *Agricultural biotechnology at the crossroads: Biological, social and institutional concerns*, edited by June F. MacDonald. Ithaca, N.Y.: National Agricultural Biotechnology Council.

Midnight Notes Collective. 1992. *Midnight oil: Work, energy, war, 1973–1992*. New York: Autonomedia/London: Central Books.

Montgomery, Scott L. 1991. Codes and combat in biomedical discourse. *Science as Culture* 2, no. 3: 341–90.

Monsanto Corporation. 1984. *Genetic engineering: A natural science*. St. Louis, Mo.: Monsanto.

Nelson, Joyce. 1990. Culture and agriculture: The ultimate simulacrum. *Border/Lines* (spring): 34–38.

NWF. 1992. Transgenic Bt plants: Moving toward the market amidst controversy. *Gene Exchange* 3, no. 1: 4–7.

Panos Institute. 1993. *Genetic engineers target third world crops*. Media Briefing no. 7. December. London: Panos Institute.

Peferoen, Marnix. 1991. Bacillus thuringiensis in crop protection. *Agro-Industry Hi-Tech* 2, no. 6: 5–10.

Pike, Keith. 1989. *Feeding the world*. Haslemere, Surrey: ICI Seeds [now Zeneca].

Pimentel, David. 1987. Down on the farm: Genetic engineering meets ecology. *Technology Review*, January, 24–30.

———. 1991. Biopesticides and the environment. In *Biotechnology and sustainable agriculture: Policy alternatives*, edited by June F. MacDonald. Ithaca, N.Y.: National Agricultural Biotechnology Council.

Pimentel, David, and Ruth Levitan. 1986. Pesticides: Amounts applied and amounts reaching pests. *BioScience* 36, no. 2: 86–91.

Proctor, Robert N. 1991. *Value-free science? Purity and power in modern knowledge.* Cambridge, Mass.: Harvard University Press.

SAGB. 1990. *Community policy for biotechnology: Priorities and actions.* Brussels: Senior Advisory Group on Biotechnology/CEFIC.

Sagoff, Mark. 1991. On making nature safe for biotechnology. In *Assessing ecological risks of biotechnology*, edited by L. Ginzburg. Stoneham, Mass.: Butterworth-Heineman.

Satelle, David. 1988. *Biotechnology . . . in perspective.* Cambridge, U.K.: Hobsons.

Schoorl, D., and J. E. Holt. 1990. Cultural change in agricultural research organizations—an urgent need. *Agricultural Systems* 32: 159–73.

SERC. 1990. *Clean technology.* Swindon: Science and Engineering Research Council.

———. 1992. *Farming as an engineering process.* Swindon: Clean Technology Unit, Science and Engineering Research Council.

Tabashnik, Bruce, Nancy Cushing, Naomi Finsen, and Marshall Johnson. 1990. Field development of resistance to Bacillus thuringiensis in diamondback moth (Lepidoptera: Plutellidae). *Journal of Economic Entomology* 83, no. 5: 1671–76.

Tabashnik, Bruce, Naomi Finsen, and Marshall Johnson. 1991. Managing resistance to Bacillus thuringiensis: Lessons from the diamondback moth (Lepidoptera: Plutellidae). *Journal of Economic Entomology* 84, no. 1: 49–55.

Taverne, Dick. 1990. *The case for biotechnology.* London: Primam.

van Rie, Jeroen. 1991. Insect control with transgenic plants: Resistance proof? *Tibtech* 9: 177–79.

Walgate, Robert. 1990. *Miracle or menace? Biotechnology and the third world.* London: Panos.

Williams, Raymond. 1980. Ideas of nature. In *Problems in materialism and culture.* London: Verso.

Wilson, F. D., et al. 1992. Resistance of cotton lines containing a Bt toxin to pink bollworm and other insects. *Journal of Economic Entomology* 85: 1516–21.

World Bank. 1992. *Development and the environment.* Washington, D.C.

Yoxen, Edward. 1983. *The gene business: Who should control biotechnology?* London: Pan.